VR Systems: Out from the Laboratory

Lawrence J. Rosenblum
Director, VR Systems and Research
Information Technology Division (Code 5580)
Naval Research Laboratory
Washington, DC 20375

Abstract

In spite of the large amount of "hype" that accompanied virtual reality (VR) earlier this decade, the field has produced only a few examples of demonstrably useful systems. Systems must be fielded and validated to show that VR is useful for purposes other than academic research. This paper discusses two VR systems developed at the Naval Research Laboratory that have received validation by statistical analysis or by user acceptance. One system focuses on experiments in shipboard firefighting to verify the effectiveness of VR as a mission planning tool. Using trained U.S. Navy firefighters, we conducted a shipboard experiment. The VR-trained firefighters performed significantly better on both navigation and firefighting tasks. The second system involved developing an application using NRL's VR Responsive Workbench to provide situational awareness inside a U.S. Marine Corps combat operations center (COC). This system has been called a major advance that is likely to eliminate paper maps in the COC.

1.0 Introduction

The concept of a natural and effective interaction between user and computer is compelling, but it has proven difficult to implement. To maintain a sense of presence (the illusion of "immersion"), frame rates must be kept high and system latency in responding to users' actions must be minimal. Interface designs to VR systems are still poorly understood and often are application specific. Disparate technologies must be integrated within the environment, often requiring an interdisciplinary team.

After a long gestation period that produced many interesting research results but few usable systems, VR is emerging as a valuable technology. User communities are accepting the value of VR, and formal testing and evaluation of VR systems are now taking place. This paper discusses experiences with two VR systems that were developed in the Virtual Reality Laboratory at the Naval Research Laboratory (NRL) and placed in the hands of a user community.

2.0 VR for Shipboard Firefighting and Damage Control

Shipboard fires are a more serious problem for the Navy than the risk of a ship sinking. Such fires can spread very rapidly and generate extremely high temperatures. Thus, shipboard survivability depends on effective firefighting when a few critical seconds determine success or failure.

2.1 Shipboard firefighting and the NRL test platform

Training Navy firefighters is expensive but, even worse, there are limited opportunities for such training, a task for which VR is well suited. Firefighters can familiarize themselves with areas of ships where they have little or no actual experience. By practicing navigation in VR, firefighters can concentrate on firefighting, rather than on navigational tasks. With virtual fire and smoke added, the virtual environment becomes sufficiently realistic so that firefighters can practice standard procedures and test tactics and strategies without endangering personnel or property.

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14. ABSTRACT
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The ex-USS Shadwell is a decommissioned ship maintained by NRL off Mobile, Alabama and is used by NRL as a firefighting and damage control research, development, test, and evaluation platform. Real-life testing of firefighting personnel aboard the Shadwell has demonstrated that key elements in successful firefighting are familiarity with the neighboring compartments and operating effectively under limited visibility conditions.

2.2 An experiment on the Shadwell

Based on our earlier work in shipboard modeling for VR, where personnel with experience aboard the Shadwell felt it gave an accurate representation of "being there," an experiment was performed to evaluate the value of VR for shipboard firefighting. An area where a shipboard experiment with trained Navy firefighters would be performed was modeled. Terrain following and collision detection restricted users to pathways and generated collisions when they walked into a table, locker, wall, or other scene element. A glove avatar allowed users to look around while walking and navigation was performed using a "fly where you point" metaphor. Buttons on a 3D joystick interactively controlled the doors. Accurate 3D models represented many of the shipboard objects, although non-interactive objects such as fire hoses were texture mapped. A dynamically growing 2D texture-mapped fire simulation provided realistic behavior and the smoke model included distant and nearby effects.

A statistical analysis of these experiments was performed [1]. Firefighters who used VR for mission rehearsal experienced a measurable improvement in the performance. These firefighters performed, on average, thirty seconds faster over a two minute navigation task to reach a predetermined location. In addition, all members of the "Traditional Training" group, who were given directions to the fire using currently standard methods, made at least one wrong turn while only one member of the VR Training group did so. For this time-critical application, both traversal time and wrong turns contribute significantly to the final success or failure. The VR Training group also had better performance on firefighting tasks. While the number of personnel taking these tasks were limited, the combined results indicate that VR provides an environment in which firefighters can familiarize themselves with ships and, with fire, smoke, and physical realism added, practice tactics for firefighting without risking lives and property.

3.0 Situational Awareness

Ranging from disaster relief through air traffic control and military operations, there are a wide variety of crisis-oriented events that need the combination of 3D visualization, detailed interaction, and the integration of real-time data feeds and information. For this, we use NRL's version of the VR Responsive Workbench [2].

3.1 The VR Responsive Workbench

The Responsive Workbench [3] is an interactive VR environment designed to support a team of end users such as military and civilian command and control specialists, designers, engineers, and doctors. The Responsive Workbench creates a match for the "real" work environment of persons who would typically stand over a table or a workbench as part of their professional routine.

The Responsive Workbench operates by displaying computer-generated, stereoscopic images onto a table (i.e., workbench) surface that is viewed by a group of users around the table. Using stereoscopic shutter glasses, they observe a 3D image displayed above the tabletop. By tracking the group leader's head movements, the Workbench permits changing the view angle and interacting with the 3D scene. Other group members observe the scene as manipulated by the group leader, facilitating easy communication between observers about the scene and defining future actions by the group leader. Perhaps the greatest strength of the Responsive Workbench is the ease of natural interaction with virtual objects. Current interactive methods emphasize gesture recognition, speech recognition, and a simulated "laser" pointer to identify and manipulate objects.

3.2 The Workbench in the field

Even with the advent of computers and sophisticated decision-making software in Marine Corps Combat Operation Centers (COC), command and control is predominantly undertaken with paper maps and acetate overlays. This is a cumbersome, time-consuming process. In addition, detailed maps and overlays can take several hours to print and distribute. There currently exists no overall picture of the

battlespace that provides a commander with a dynamic range of resolution sufficient to track units ranging from aircraft carriers to six-Marine fire teams.

As part of a U.S. Marine Corps experiment in March 1997, we displayed on the Workbench map-quality 3D terrain resolution of Twentynine Palms, California (62 by 72 Km) and inserted a virtual "ocean" outside a road network bordering Twentynine Palms [4]. The terrain was textured with line-drawing maps at a geographic resolution of 1:25,000. Both models and Intelligence Preparation of the Battlefield (IPB) icons were used to represent objects to be placed on the terrain. The models and IPB icons were selected and modified through discussions with the Marines.

Interactive methods for the Workbench include gesture recognition using a pinchglove, speech recognition, and a simulated laser pointer. The latter was used for this system because of its robustness when employed by a variety of users. When the laser intersects the terrain, it's as if the user's hand was attached. Lateral hand movements pan the terrain, while vertical movements zoom in and out. Rotating the laser pointer rotates the image. Additional modes use the simulated laser to pick up and move objects, to query objects, to measure distances and headings, and to perform several other tasks.

The next step for our situational awareness system will be the far more challenging case of an urban environment. Modeling, visualization, and interactions are significantly more difficult in the "urban canyon." Additional figures from the 1997 experiment and a CNN Headline News segment showing the Workbench in the "Blue Team" COC can be found on our homepage: www.ait.nrl.navy.mil/vrlab.

4.0 Other VR Systems

We briefly mention two other VR systems of interest that have undergone evaluation either through statistical testing or through user acceptance with additional analysis.

4.1 The acrophobia project at the Georgia Institute of Technology

This project used virtual reality to examine fear of heights, which is clinically defined by anxiety upon exposure to heights, avoidance of heights, and having the fear interfere with normal daily functions. In normal treatment, the psychologist will accompany the patient through a succession of tasks involving height with the task difficulty increasing. Thus, using VR offers several advantages: lower cost (less time spent by the psychologist who need not accompany the patient on tasks), a less intimidating environment, and safety. The virtual reality treatment comprises three stages: a virtual "see-out" elevator inside a 49-story virtual hotel, balconies of several different heights, and bridges over a river and through a canyon. This research included careful statistical evaluation that demonstrated its effectiveness [5].

4.2 The NASA Hubble space telescope repair mission

In 1990, following the launch of the Hubble Space Telescope, astronomers discovered flaws in its optical systems. Training for a repair mission became a major NASA effort, including the use of VR [6]. By using VR to immerse the repair team in their operating environment, they were provided with knowledge of both the telescope hardware and repair procedures. The training enhanced both cognitive and psychomotor skills, and the repair mission was successful. A post-flight survey was used to conduct an analysis demonstrating that members of the flight team judged, on average, that the VR training had a positive effect on their performance during the mission. Moreover, audio and visual cues were judged to have helped the participants. Discomfort in the virtual environment had a negative but acceptable impact on team members.

5.0 Conclusions

It has taken at least a half-decade longer than anticipated, but VR is moving out of the research laboratories and into the hands of users across many applications. Situational awareness and crisis planning, medicine, and engineering design are disciplines that are leading the way. We anticipate that the year 2000 will see VR truly benefiting society.

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